X-653-62-2

NASA TMX 55556

STATEMENT OF WORK FOR STUDIES OF AEROS SYSTEMS PROBLEMS

PREPARED BY
SYSTEMS ENGINEERING BRANCH
AERONOMY AND METEOROLOGY DIVISION

REVISED

MAY 22, 1962

NASA — GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

1. INTRODUCTION

The NASA long-range program for the development of a global meteorological satellite system proposes the launch of the meteorological satellite, AEROS, into a synchronous orbit. The general mission of AEROS is discussed in Appendix A.

Solution of the technical problems of orbit injection, attitude control, temperature control, communications, sensors and operating lifetime will represent necessary steps in the achievement of the mission.

As a step in the accomplishment of this mission, the Goddard Space Flight Center will initiate a number of contracts for the study of the spacecraft and the ground station systems problems. The duration of the system studies shall be four (4) months. These studies will <u>not</u> be the immediate predecessors of future contracts for system hardware.

2. PURPOSE OF THE SYSTEM STUDY

The purpose of the System Studies shall be:

(a) To find the most reasonable and reliable systems for bringing maximum areas of the Earth under constant observation.

(b) To identify the critical scientific and engineering problem areas and the advances in technology required for successful achievement of the mission.

3. SCOPE

3.1 This document defines the requirements for a System Study for the AEROS Meteorological Satellite and its Ground Station Equipment.

3.2 The study shall be of four (4) months' duration.

3.3 The study shall meet the system requirements set forth in this document and shall include:

a. Detailed examination of the technical problems to be solved.

b. A proposed solution of each problem including the comparative data of the various alternatives examined.

c. A proposed solution of each problem within the present and anticipated state of the art.

d. A proposed solution of each problem with reliability adequate to achieve a lifetime of one year in orbit.

4. TECHNICAL OFFICER

4.1 A Technical Officer shall be designated by NASA/GSFC to direct the contractor's efforts in meeting the requirements of this study.

4.1.1 The Technical Officer will monitor closely the progress during the course of the study, review all of the reports, and effect close liaison between the contractor and NASA/GSFC.

5. GENERAL CONSTRAINTS

5.1 The following constraints are imposed upon this study program.

a. This effort shall be limited to a single spacecraft/ground complex system. The spacecraft shall be centered over the Equator at about 90° W. longitude.

b. The launch schedule shall be no earlier than CY1966.

c. The launch vehicle shall be a standard National vehicle not larger than an Atlas Centaur.

d. Injection and stabilization of the satellite shall NOT require an original basic modification of the launch vehicle, including guidance system.

e. The contractor shall not engage in any studies of the meteorological requirements for the AEROS System. The meteorological requirements are: (See Appendix A)

(1) Twenty-four (24) hour surveillance of the Earth's cloud cover.

(2) The determination of the cloud cover over the disc of the Earth within view of the Spacecraft and the assessment of the details of cloud systems in selected areas within this disc.

(3) Infrared measurement of the Earth's heat budget.

(4) Cloud cover data shall be obtained at least once every thirty minutes.

f. The antenna for the command and data acquisition site shall be limited to one having comparable performance to a single 85' dish installation, capable of operating up to 2300 mc.

6. REQUIREMENTS

6.1 For the purposes of this study, AEROS shall be considered as a single Earth-stabilized spacecraft, placed in a synchronous orbit at an altitude of approximately 22,240 statute miles. The design shall stress simplicity and reliability and a satellite lifetime objective of one (1) year. Primary sensory instrumentation will provide day and night cloud cover surveillance and infrared measurements.

Examination of the following categories is considered to be the minimum required to accomplish the purposes of this study.

a. The launch vehicle requirements.

b. Differing possible orbits.

c. Station keeping.

d. Meteorological sensors.

e. Attitude Control

f. Communications

g. Power

h. Other spacecraft instrumentation.

i. Spacecraft configuration.

j. Thermal control.

k. Ground Station Equipment.

In examining these categroies, the various trade-offs, including their ability to meet the meteorological requirements, shall be considered.

6.2 Orbit Determination

The contractor shall examine the technical problems attendant with injection into a synchronous orbit of an AEROS spacecraft whose weight shall be consistent with the mission requirement. The contractor shall provide studies of the resultant orbits based on the following typical injection errors for a satellite stationed over about 90° W. longitude.

a. Period error = 1000 seconds

b. Eccentricity variation from zero = .013

c. Inclination error = 0.8 degrees

d. Longitude error = 0.3 degrees

6.3 Station Keeping

Based on the results of the orbital calculations, the contractor shall examine various methods for station keeping in order to maintain the AEROS Spacecraft in position with respect to the Earth.

The study shall include such problems as they pertain to the AEROS System:

a. Methods of error detection.

b. Computation of correction.

c. Whether corrections should be automatic or on command.

d. Damping to prevent hunting or searching for position.

e. Resonance of perturbations due to the ellipticity of the Earth at the Equator.

f. Influence of gravity due to effects of the Sun, Moon, magnetic fields, etc., to be stated in numerical form.

g. Radiation pressure on the spacecraft.

6.4 Sensors

The study of the sensors shall be limited to those which accomplish the following meteorological measurements:

a. Twenty-four hour surveillance of cloud cover.

b. Measurement of the Earth's heat budget.

The study shall provide detailed information on the variation of solar and terrestrial radiation intensity within the field of view of the spacecraft as a function of time of day. The Contractor shall examine such problems as the ability of the sensor to provide satisfactory information when the field of view encompasses sunrise or sunset on one edge of the Earth and moonless conditions on the other.

The contractor shall provide studies of the effects of all motions in the spacecraft on the sensors. The contractor shall provide sensory system power consumption profiles.

6.5 Attitude Control

The contractor shall provide a proposed design for an attitude control system. The control system shall provide spacecraft attitude and attitude rates consistent with the performance of the meteorological sensors recommended in the contractor's study.

The contractor shall propose a method of attitude sensing and provide a detailed study of all such sensors and sensor systems required.

The contractor shall propose a method of maintaining attitude and shall provide detailed data which indicates his examination of the use of reaction wheels, gyros, reaction spheres, jets, etc., to provide spacecraft torquing.

The contractor shall provide detailed data on the effects on the spacecraft attitude due to disturbances arising from:

a. Motion of the solar array.

b. Station keeping.

c. Gas expulsion.

d. Sensor motion.

e. Other possible internal motions.

f. External forces.

6.6 Communications

The contractor shall provide studies for a communications system. He shall propose a system which is consistent with the requirements of his sensors and the interrogation rate of the satellite.

The contractor shall provide data on the trade-offs of such items as frequencies, analog versus digital communications, transmission bandwidth, transmission methods (AM, FM, etc.), the signal-to-noise ratio required, etc.

The contractor shall propose an antenna system for the spacecraft and provide supporting data.

6.7 Power

The contractor shall provide a detailed power profile required to perform the mission of the spacecraft. The contractor shall then examine the attitude of the spacecraft with respect to the sun and propose a solar power supply to enable spacecraft to carry out its mission. If the contractor porposes a solar array and batteries, an array configuration and orientation shall be specified along with a proposed weight.

6.8 Other Spacecraft Instrumentation

The contractor shall propose a compatible command system for the spacecraft.

The contractor shall provide design data on the spacecraft command antenna, receiver and circuitry.

The contractor shall propose a telemetry system for housekeeping purposes.

The contractor shall provide data on sampling times, method of transmission of data, etc. The telemetry system shall provide the capability for determining launch performance and shall be compatible with present NASA telemetry and range systems.

6.9 Spacecraft Configuration

The contractor shall generate a preliminary spacecraft configuration consistent with the basic scientific mission of the AEROS satellite and the characteristics of the launch vehicle. The spacecraft shall provide adequate visibility for the Earth and Sun sensors unrestricted by other portions of the satellite or its control systems.

The contractor shall provide data on the proposed weight, moment of inertia, structural design, center of gravity, choice of materials. Due to the high altitude of the planned orbit, careful consideration shall be given to the accurate alignment of the Earth-viewing sensors.

The contractor shall consider as part of his design the problem of testing the spacecraft attitude and station keeping system in a thermal vacuum chamber.

6.10 Thermal Control

The contractor shall propose a method for maintaining the satellite temperature within narrow limits in order to increase the reliability of the spacecraft, and shall develop data which will indicate thermostating complexity and weight versus temperature range.

The contractor shall provide detailed studies of the solar heating of the spacecraft and of the heat dissipated internally and radiated to space.

6.11 Ground Station Equipment

The contractor shall provide studies of the ground station equipment required as part of the AEROS System. Ground station equipment is limited to two types of data sites:

a. A single primary command and data acquisition site.

   This site will be located on the North American Continent.

b. Multiple data acquisition sites.

   These sites will be scattered over the Earth, within line of sight of the spacecraft. These shall be economical sites and are intended for data acquisition only. A method of direct data readout in image form shall be considered as part of the system.

The contractor shall provide data on the equipment requirements for such sites and propose instrumentation for accomplishing the mission of these sites.

6.12 Data Handling

It is not the objective of this contract to include a study of data processing procedures; however, the contractor shall consider the initial presentation of data to the ground station in such a format as to facilitate its assimilation for immediate operational and preliminary research use.

7. DELIVERIES

7.1 Monthly Report

The contractor shall provide monthly progress letters. The progress letters shall contain a summary of technical progress during the preceding period and the following fiscal information: A summary of funds allocated, funds expended and anticipated expenditures to completion. Three copies of such reports shall be sent to NASA, one to the Goddard Space Flight Center Contracting Officer and two to the NASA/GSFC Technical Officer within ten (10) days from the close of the reporting period.

7.2 Final Report

Fifty (50) copies of a comprehensive and conclusive final report shall be delivered to GSFC on the last day of the contract period. This report shall include all drawings, computations, sketches, and information developed during the study, including comparative data on the various alternatives studied, presented in nomograph or tabular form, and shall be sufficiently comprehensive and conclusive to form the basis for development of the specifications for the AEROS Satellite System by the National Aeronautics and Space Administration.

7.3 Models

The contractor shall deliver one (1) one-quarter (1/4) scale mock-up of the mechanical configuration of the AEROS Satellite, together with the final report called for in Section 7.2 of this specification.

AEROS

APPENDIX "A"

Many atmospheric processes of interest to the Meteorologist can be inferred from the accompanying clouds produced by these processes. The type, size, amount and distribution of clouds are useful in interpreting the state of the atmosphere and atmospheric motions.

The atmosphere rarely moves in straight lines over extended distances; there are turbulent eddies, convection cells, cyclonic vortices (hurricanes, tornadoes, cyclones, large storms) anti-cyclonic motion in regions of high pressure, and waves ranging up to a few thousand miles in wavelength. Thus, the size or wavelength of these patterns vary from a few inches (smallest turbulent eddies readily identifiable) to several thousand miles (planetary waves). In many cases, several scales of motion are super-imposed, so that the Meteorologist may find such phenomena as a tornado in a larger cyclonic circulation.

It has often been said that Meteorologists wish to observe the atmosphere "everywhere all of the time". Our desire to meet such an objective must be tempered by consideration of means to process, assimilate and disseminate such observations, as well as by economic considerations. As a result, samplings in both time and space are dictated.

In a very general sense, the frequency of observations in both time and space required to reasonably describe weather systems or atmospheric motions is inversely proportional to the size or wavelength of these patterns. This general rule can be used as a guide in determining the frequency of temporal and spatial sampling. A few examples may be useful.

Severe local storms (such as thunderstorms, hail, tornadoes) are usually associated with cumulonimbus-type clouds, these clouds serving as indicators of the probable existence of severe weather. Such clouds may exist singly or in merged groups varying in horizontal size from a few tens to a few hundred miles. Such clouds can develop from smaller cumulus in less than an hour; their life cycle may vary from one to several hours with significant changes occurring during the cycle. <u>To reasonably describe this phenomenon, observations would be desirable every few miles and with a frequency of three or four times per hour.</u> (See papers by Tepper and Fujita)

Planetary waves are horizontal undulations in the upper level winds circling the Earth and having a wavelength of a few thousand miles. The so-called "jet streams" are associated with such waves. Because of the size and the usually slow rate of change of these waves, <u>observations spaced by a few hundred miles obtained at six to twelve hourly intervals are generally adequate.</u>

The generalities in the preceding paragraphs must be moderated when considering the use of cloud imaging to infer air motions and the state of the atmosphere. For example, in weather forecasting, it is not necessary to measure the location and life cycle of individual, small cumulus clouds (such as "fair weather" **cumulus**) which generally are a few hundred to a few thousand feet in horizontal extent and whose life cycle is considerably less than an hour.*

In discussing cloud imaging, consideration also must be given to contrast. One must (or would like to) be able to detect clouds against a background of snow, ice, or desert sands. The ability of the eye or similar sensor in detection is a function of both resolution and contrast. For example, on only a few occasions was it possible to see the eye of hurricanes, which determines the location of the center of the storm, in TIROS III pictures, because of the low contrast-resolution.

In developing the AEROS Meteorological Satellite System concept we are concerned with research in atmospheric physics for meteorological purposes. The development of AEROS is in itself an experiment which represents one element of a system for weather analysis and forecasting.

It may be useful to consider the general classes of weather analysis, forecasting and dissemination centers where data from such a system would be used. Three types of centers will be discussed briefly: The global or hemispheric analysis center (such as, the National Meteorological Center of the U.S.Weather Bureau in Washington, D.C.); regional forecast center (Area Forecast Centers of the Weather Bureau, for example, which forecast cognizance of an area embracing one or more States); and, local weather offices.

The primary function of the National Meteorological Center (NMC) is to produce weather analyses and prognostic charts on a hemispheric (and eventually global) scale. For this purpose, <u>synoptic</u> observations every six hours are desired. Major features of the wind flow, storms, fronts, atmospheric stability, etc., are required. The products of the NMC are sent to the Area Forecast Centers (AFC) and local weather offices.

The regional or area forecast centers are concerned with analysis and forecasting for areas of widely varying size up to a few thousand miles. They make use of the NMC products, but also require more detailed data for their area of responsibility. Observations generally are required on an

---

*This refers to the life cycle of a single cloud. When such clouds exist in the atmosphere, they are constantly generating and dissipating, giving the appearance of persistence to the non-critical observer. However, the distribution (random, long lines or "streets", circular arrays or Benard-like patterns, etc.) and horizontal extent of a field of such cumulus clouds are very important. Such patterns generally range in size from about ten to several hundred miles. Thus, while the meteorologically significant dimension in this case exceeds ten miles, the existence of much smaller clouds must be detected by the sensory system.

hourly basis plus special observations of significant changes in weather. Many Centers are concerned with mesoscale forecasting. For example, the Center at Kansas City forecasts severe local storms, such as thunderstorms, hail, tornadoes, in the midwestern United States.

The local weather offices adapt forecasts prepared by the NMC and AFC's for users in a specific metropolitan area or homogeneous agricultural region. Fairly detailed observations at very frequent intervals are desired for distances of up to a few hundred miles from the station. Often these offices are situated at airports and provide important weather services to aviation. Air and landing traffic control in the vicinity of the airport requires nearly continuous observations in the area up to fifty to one hundred miles from the airport. Secondly, many of these stations brief pilots on the weather expected on their routes which extend over ever-increasing distances in the jet age. These route weather depictions and forecasts utilize maps and cloud analyses issued by the NMC and certain AFC's.

In summary, it is seen that, in general, the area of interest decreases and the frequency (in both space and time) and detail of measurements increases from the global center (NMC) to the local weather office.

In the next few years there are certain changes likely in the weather analysis and forecasting system organization as a result of new technology. Advances in numerical weather analysis and prediction using high speed data processing equipment, are resulting in automation of many functions, improvement in the accuracy of the results, and generation of new products. Current research indicates it may soon be possible to apply automatic numerical prediction techniques to local forecasting. However, the cost and complexity of the equipment required and the need for highly skilled persons who are in limited supply make it probable that there will be increased centralization of analysis and forecast functions. This trend also is indicated by the advent of the polar-orbiting Nimbus satellite now under construction by the National Aeronautics and Space Administration which will be used in the early phases of the National Operational Meteorological Satellite System (NOMSS), now NOS. Initially at least, the operationally useful data will be available in their greatest detail at the NMC. This is dictated by the bandwidth of communications required for data transmission, the high cost and complexity of the data processing and analysis equipment, and the skilled personnel required.

The future may see local weather offices, and to a lesser extent, AFC's, as "marketeers" of weather information. Satellite observations transmitted directly to such points would have to be produced in a form that could be directly applied. Economic considerations will dictate that the local reception, processing and display equipment be relatively low in cost and operated and maintained by a small number of moderately-skilled (semi-professional) technicians.

BIBLIOGRAPHY

Erickson, C.O. and Hubert, L.F.: "Identification of Cloud Forms from TIROS I Pictures", U.S.W.B., MSL Report No. 7 (1961).

Fritz, S.: "On Observing the Atmosphere from Satellites -- I. Cloud Observations". Weatherwise, Volume 12, P.139 (1959).

Johnson, D.S.: "Image Sensing as Applied to Meteorological Satellites", J.S.M.P.J.E., Volume 69, pp. 14-18 (1960).

U.S. Weather Bureau: Technical Planning Study No. 2 (1960). (Discusses space and time sampling of observations for various forecast applications).

Tepper, M.: Meso-Meteorology -- The Link Between Macrosynoptic Weather and Local Weather, American Meteorological Society Bulletin, Volume 40, No. 2, (1959).